METHODS AND APPARATUS FOR EFFECTUATING A LASTING CHANGE IN A NEURAL-FUNCTION OF A PATIENT

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/217,981, filed July 31, 2000, which is incorporated herein in its entirety.

TECHNICAL FIELD

Several embodiments of methods and apparatus in accordance with the invention are related to electrically stimulating a region in the cortex or other area of the brain to bring about a lasting change in a physiological function and/or a mental process of a patient.

BACKGROUND

A wide variety of mental and physical processes are known to be controlled or are influenced by neural activity in particular regions of the brain. In some areas of the brain, such as in the sensory or motor cortices, the organization of the brain resembles a map of the human body; this is referred to as the "somatotopic organization of the brain." There are several other areas of the brain that appear to have distinct functions that are located in specific regions of the brain in most individuals. For example, areas of the occipital lobes relate to vision, regions of the left inferior frontal lobes relate to language in the majority of people, and regions of the cerebral cortex appear to be consistently involved with conscious awareness, memory, and intellect. This type of location-specific functional organization of the brain, in which discrete locations of the brain are statistically likely to control particular mental or physical functions in normal individuals, is herein referred to as the "functional organization of the brain."

Many problems or abnormalities with body functions can be caused by damage, disease and/or disorders of the brain. A stroke, for example, is one very common condition that damages the brain. Strokes are generally caused by emboli (*e.g.*, obstruction of a vessel), hemorrhages (*e.g.*, rupture of a vessel), or thrombi (*e.g.*, clotting) in the vascular system of a specific region of the cortex, which in turn generally causes a loss or impairment of a neural function (*e.g.*, neural functions related to face muscles, limbs, speech, etc.). Stroke patients are typically treated using physical therapy to rehabilitate the loss of function of a limb or another affected body part. For most patients, little can be done to improve the function of the affected limb beyond the recovery that occurs naturally without intervention. One existing physical therapy technique for treating stroke patients constrains or restrains the use of a working body part of the patient to force the patient to use the affected body part. For example, the loss of use of a limb is treated by restraining the other limb. Although this type of physical therapy has shown some experimental efficacy, it is expensive, time-consuming and little-used. Stroke patients can also be treated using physical therapy plus adjunctive therapies. For example, some types of drugs, such as amphetamines, that increase the activation of neurons in general, appear to enhance neural networks; these drugs, however, have limited efficacy because they are very non-selective in their mechanisms of action and cannot be delivered in high concentrations directly at the site where they are needed. Therefore, there is a need to develop effective treatments for rehabilitating stroke patients and patients that have other types of brain damage.

Other brain disorders and diseases are also difficult to treat. Alzheimer's disease, for example, is known to affect portions of the cortex, but the cause of Alzheimer's disease and how it alters the neural activity in the cortex is not fully understood. Similarly, the neural activity of brain disorders (*e.g.*, depression and obsessive-compulsive behavior) is also not fully understood. Therefore, there is also a need to develop more effective treatments for other brain disorders and diseases.

The neural activity in the brain can be influenced by electrical energy that is supplied from an external source outside of the body. Various neural functions

can thus be promoted or disrupted by applying an electrical current to the cortex or other region of the brain. As a result, the quest for treating damage, disease and disorders in the brain have led to research directed toward using electricity or magnetism to control brain functions.

One type of treatment is transcranial electrical stimulation (TES), which involves placing an electrode on the exterior of the scalp and delivering an electrical current to the brain through the scalp and skull. Patents directed to TES include: U.S. Patent No. 5,540,736 issued to Haimovich et al. (for providing analgesia); U.S. Patent No. 4,140,133 issued to Katrubin et al. (for providing anesthesia); U.S. Patent No. 4,646,744 issued to Capel (for treating drug addiction, appetite disorders, stress, insomnia and pain); and U.S. Patent No. 4,844,075 issued to Liss et al. (for treating pain and motor dysfunction associated with cerebral palsy). TES, however, is not widely used because the patients experience a great amount of pain and the electrical field is difficult to direct or focus accurately.

Another type of treatment is transcranial magnetic stimulation (TMS), which involves producing a high-powered magnetic field adjacent to the exterior of the scalp over an area of the cortex. TMS does not cause the painful side effects of TES. Since 1985, TMS has been used primarily for research purposes in brain-mapping endeavors. Recently, however, potential therapeutic applications have been proposed primarily for the treatment of depression. A small number of clinical trials have found TMS to be effective in treating depression when used to stimulate the left prefrontal cortex.

The TMS treatment of a few other patient groups have been studied with promising results, such as patients with Parkinson's disease and hereditary spinocerebellar degeneration. Patents and published patent applications directed to TMS include: published international patent application WO 98/06342 (describing a transcranial magnetic stimulator and its use in brain mapping studies and in treating depression); U.S. Patent No. 5,885,976 issued to Sandyk (describing the use of transcranial magnetic stimulation to treat a variety of disorders allegedly related to deficient serotonin neurotransmission and impaired pineal melatonin functions); and